METHOD AND APPARATUS FOR PRODUCING DEMAND REAL-TIME TELEVISION

CROSS-REFERENCE TO A RELATED APPLICATION

5   The disclosure contained in this application is related
       to U.S. patent application serial number 09/201,529
       (attorney docket number 167), filed simultaneously herewith
       and herein incorporated by reference.

10   BACKGROUND OF THE DISCLOSURE

           1. Field of the Invention
           The invention relates to video-on-demand systems and,
15   more particularly, the invention relates to a method and
       apparatus for generating a real-time video bitstream for
       transmission through a video-on-demand system as well as
       simultaneously storing the video information in a format
       that facilitates demand television, i.e., a play bitstream,
20   a fast forward bitstream and a fast reverse bitstream that
       are derived from the real-time video bitstream content.

           2. Description of the Background Art

25   In a video-on-demand system such as the OnSet™ system
       manufactured by DIVA Systems Corporation, a file server is
       used for streaming video information to users (subscribers)
       of the system. The OnSet™ system is described in U.S.
       patent application serial number 08/984,710, filed December
30   3, 1997, and the file server is described in U.S. patents
       5,671,377 and 5,581,778. The disclosures of this
       application and these patents are incorporated herein by
       reference. The OnSet™ system contains service provider
       equipment coupled through an information distribution
35   network to subscriber equipment. This system provides
       subscribers VCR-like controls to enable a subscriber to
       select information content, for example, a movie, then play,
       fast forward, rewind, pause, or stop the selected movie.
       The subscriber enters control commands through the

subscriber equipment and the service provider equipment
executes the commands to fulfill the purpose of the command,
e.g., play, fast forward, rewind, stop or pause the movie.

A file server forms a portion of the service provider
5 equipment and stores, for a given movie, a standard play
stream (i.e., an MPEG-2 compressed video bitstream), a fast
forward stream and a fast reverse play (rewind) stream. The
fast forward and fast reverse streams are also MPEG-2
compressed video, where the fast forward stream is a
10 compressed signal containing only every Nth frame of the
uncompressed play video and the fast reverse stream is a
compressed signal containing every Nth frame of the
uncompressed play video played backwards. To store the
video information, each stream is divided into portions
15 (e.g., N-byte segments of compressed data) and striped onto
a disk array. The disk array stores all the information
that the file server can directly access.

The process for generating the fast forward and fast
reverse streams is performed in a non-real time manner such
20 that the video content is pre-encoded and stored in the file
server. The process requires a frame by frame analysis of
the video stream to enable the frames to be encoded in an
MPEG-2 compliant form, yet provide a fast forward and fast
reverse effect when decoded. As such, the video sequence is
25 processed to extract every Rth frame (i.e., one of every R
frames, where R is an integer greater than 1) to form a fast
forward sequence and then the fast forward sequence is
encoded (compressed). For a fast reverse stream, a sequence
of frames in reverse order is created and encoded. This
30 encoding process can not be used for producing fast forward
and fast reverse streams in real time such that a real time
program can be encoded and stored for almost immediate use
of VCR-like functions.

Therefore, there is a need in the art for an improved
35 encoding system for a video-on-demand system to ensure near
real-time availability of fast forward and fast reverse
functions and real-time availability of a high bit rate

video bitstream that, when decoded, produces a play
sequence.

SUMMARY OF THE INVENTION

5   The disadvantages associated with the prior art are
overcome by the invention of a demand television system that
simultaneously encodes a broadcast video frame sequence into
a broadcast bitstream and a storage bitstream. The
10 broadcast bitstream is broadcast to system subscribers as
the sequence is encoded, while the storage bitstream is
stored in an information server. The subscriber may, at any
time during the broadcast, elect to review content of the
broadcast that was previously displayed. Upon electing to
15 review, the system transmits the storage bitstream to the
subscriber in a pointcast manner. The storage bitstream
contains, for example, a plurality of selectable types of
bitstreams including fast forward, fast reverse and standard
play. As such, by requesting particular functions, the
20 subscriber is provided with VCR-like functions for a
broadcast program.
        To facilitate this functionality, a video encoder that
simultaneously produces an MPEG-2 compliant fast forward,
fast reverse and play bitstreams from a sequence of video
25 frames, e.g., 601-format video, as well as a real-time
bitstream for real-time transmission to the user as a
broadcast transmission. The encoder of the present
invention contains a broadcast encoder and a storage
encoder. The broadcast encoder encodes the video frame
30 sequence using, for example, a high bit rate encoder to
ensure accurate encoding and transmission of sporting
events. While simultaneously the storage encoder subsamples
the video sequence, extracts a plurality of frames from the
video sequence and buffers the subsampled frames.
35 Simultaneous with the subsampling and buffering, the storage
encoder also encodes the source frames within a real-time
encoder, e.g., an MPEG-2 encoder, to form a standard play
bitstream for storage within the file server.

As the play bitstream is being encoded, the buffered frames are recalled from the buffer and coupled to a second real-time encoder. The second encoder forms both the fast forward and fast reverse bitstreams using a time

5   multiplexing technique wherein a group of pictures (GOP) for the fast forward stream can be formed, followed by the compression of the same GOP having the frames organized in reverse order. As such, the compressed GOPs are represented by the fast forward and fast reverse bitstreams. The play,

10 fast forward, and fast reverse bitstreams for each GOP are organized into a file and stored on the mass storage device (e.g., disk drive array) of the file server.

While the bitstreams that facilitate the VCR-like functions are being encoded and stored, the high bit rate

15 encoded signal is broadcast to subscribers. As such, the subscriber may watch an event (e.g., a sporting event) in real-time, then elect to "rewatch" a previously viewed portion of the real-time event. The viewer merely depresses a "rewind" or reverse button on a remote control and the VOD

20 system accesses the stored event files and "plays" the fast reverse bitstream. As such, the viewer is provided with the sense of a VCR rewind function. At an appropriate location the viewer depresses a "play" button and the stored standard play bitstream is transmitted to the viewer. The viewer may

25 "catch up" to the real-time event by either depressing a fast forward button or a "real-time" button. The fast forward button causes the stored fast forward bitstream to be transmitted to the viewer to provide a sense of a VCR fast forward mode and, when the fast forward bitstream

30 exhausts the available data, the system automatically switches back to the real-time bitstream. The "real-time" button causes the system to instantly switch back to the real-time bitstream.

BRIEF DESCRIPTION OF THE DRAWINGS

The teachings of the present invention can be readily understood by considering the following detailed description in conjunction with the accompanying drawings, in which:

5

FIG. 1 is a block diagram of a video-on-demand system that operates in accordance with the present invention;

FIG. 2 depicts a block diagram of the encoder of the present invention;

10

FIG. 3 illustrates the method of the present invention used to produce a fast forward bitstream;

FIG. 4 illustrates the method of the present invention used to produce a fast reverse bitstream; and

FIG. 5 illustrates the interaction model between the

15

service provider equipment and subscriber equipment.

To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures.

20

DETAILED DESCRIPTION

FIG. 1 depicts a high level block diagram of the illustrative information distribution system 100 that incorporates the present invention. The system 100 contains

25

service provider equipment 102, a communications network in the form of a cable transport subsystem 104 and subscriber equipment 106_n, where n is an integer greater than 0. The service provider equipment 102 contains an information server 108 which is typically a parallel processing computer

30

containing at least one central processing unit 110 and associated memory 112. U.S. patent number 5,671,377, issued September 23, 1993 and U.S. patent number 5,579,527, issued November 26, 1996, which are hereby incorporated herein by reference, describe a server that is capable of operating in the capacity of information server 108. The server 108

35

interacts with the data storage device 114 (e.g., a disk drive array) that generally stores the subscriber information (e.g., video data) that is transmitted directly

to the subscriber equipment 106 as well as recalled and
downloaded to the subscriber equipment 106. The video data
is produced by an encoder 200 as two streams: the first is
a stream containing a real-time bitstream of encoded video
5 information that is to be broadcast to the subscribers
(referred to herein as the broadcast stream), the second is
a stream containing a non-real-time bitstream of encoded
video information that is stored by the information server
to facilitate VCR-like functions (referred to herein as the
10 storage stream).

Additionally, within the service provider equipment 102
is a video session manager 122 that provides session control
of the information flowing to and from the server 108. The
video session manager 122 contains its own central
15 processing unit (CPU) 124 and associated memory 126 that
provides functionality for the graphical user interfaces
through which the consumer interacts with the system. The
CPU 124 is part of a session control manager 125 that
controls a plurality of modems 127 that facilitate
20 communication with the subscriber equipment. Other
subsystems of the service provider equipment include a
network manager 142 and a back office subsystem 144. These
subsystems maintain certain databases of information that
enable the system to accurately control system access,
25 subscription package definitions, and subscriber/consumer
profile and billing.

The information server 108 is coupled to the video
session manager 122 via data path 116, synchronization clock
path 118, and control path 120. The server 108 provides
30 data streams that are destined for consumers on path 116 and
a synchronization clock on path 118. The specific data
streams are provided in response to requests for information
(e.g., menu applets, video programs, and other content
material) from the video session manager 122 on path 120.
35 These data streams are packetized and modulated onto a
carrier that is compatible with the transmission
requirements of the network 104.

The video session manager 122 accomplishes all of the
transmission interface requirements of the system 100 as
well as provides graphical user interface support.
Specifically, the video session manager 122 is coupled

5 through the modems 127 to subscriber equipment via a forward
information channel 132, a forward command channel 133 and a
back channel 134. All three of these channels are supported
by the cable transport subsystem 104. The video session
manager 122 contains a modulator for modulating the server

10 data streams onto one or more carrier frequencies for
transmission on the forward information channel 132.
Additionally, modems 127 within the video session manager
122 send control information via the forward command channel
and receive control information via the back channel.

15 Moreover, a conventional cable television signal source 128
is optionally coupled to the forward information channel via
a signal coupler 130. In operation, the video session
manager 122 responds to requests from the subscriber
equipment 106 for interactive menus and data streams by

20 requesting the server 108 to provide such information, then
communicating that information to the requesting subscriber
equipment 106. The video session manager 122, as discussed
below, also ensures that the subscriber equipment 106 is
authorized to receive the requested information.

25 The cable transport subsystem 104 can be any one of a
number of conventional broad band communications networks
that are available such as a fiber optic network, a
telephone network, existing cable television network and the
like. For example, if the network is a hybrid fiber-coax

30 network, the transport technique used in both forward
channels may be modeled after the moving pictures expert
group (MPEG) transport protocol for the transmission of
video data streams. In general, the transport mechanism for
both the forward channels and transport information to the

35 subscriber equipment must be able to carry unidirectional,
asynchronous packetized data such as that defined in the
MPEG video and audio signal transmission protocol, and the

like.   There are a number of such transport protocols
available.

     The subscriber equipment 106 receives the requested
data streams as well as broadcast streams from the forward
5 information channel, demodulates the streams and processes
them for display on the display device 140 (e.g., a
conventional television).   In addition, the terminal 136
accepts commands from a remote control input device 138 or
other input device to facilitate consumer interaction with
10 the system.   These commands are formatted, compressed,
modulated, and transmitted through the network 104 to the
video session manager 122.   Typically, this transmission is
accomplished through the back channel 134.   These commands
are preferably transmitted through the same network used to
15 transmit information to the subscriber equipment.   However,
the back channel coupling the subscriber equipment to the
server may be a separate network, e.g., a forward
information channel through a television cable network and a
back channel through a telephone network.   The telephone
20 network could also support the forward control channel.   The
video session manager 122 interprets each command set from
the terminal through the back channel and instructs the
information server to perform certain functions to implement
the consumer/subscriber request.

25   FIG. 2 depicts a block diagram of the encoder 200
comprising a broadcast encoder 250 and a storage encoder
255.   The broadcast encoder a source video sequence in a
conventional manner, i.e., compressing the source video
sequence in real-time as the frames are input to the
30 encoder.   For example, this encoder may be a high speed
encoder such as an 8 Mbps MPEG-2 encoder that accurately
encodes such difficult to compress programming such as
sporting events.

     The storage encoder 252 comprises a first encoder 202,
35 frame subsampler 204, a frame buffer 206, a second encoder
208 and a controller 210.   The first encoder 102 encodes a
source video sequence in a conventional manner, i.e.,
compressing the source video sequence in real-time as the

frames are input to the encoder. The second encoder 208
operating in conjunction with the subsampler 204 and the
buffer 206 encodes a subsampled version of the source video
sequence to form a fast forward and fast reverse bitstreams
5   (collectively referred to herein as trick play bitstreams or
trick play streams). The first encoder (the play stream
encoder 202) contains a real-time MPEG-2 encoder that
produces an MPEG-2 compliant, compressed video bitstream (a
play stream) from a sequence of 601-format video frames.
10 The second encoder (the trick play stream encoder 204) is
also an MPEG-2 real-time encoder 212.

For the following discussion, frame numbering is used
to describe the temporal order in which frames occur in
source material where 1 is the first frame in the source
15 material frame sequence and 2 is the second frame and so on.
For the following description, R is an integer and defines a
play-back speed multiplier which has significance in the
trick play processes. The speed multiplier R is a variable
that is established by the controller 210. Throughout this
20 disclosure, the exemplary trick play streams are fast
forward and fast reverse. Of course other forms of trick
play streams may be generated using the encoder 200 of the
present invention. If the multiplier R equals 2, playback
(decoding) of a fast forward stream is twice normal single
25 speed. If R equals 3, playback is three times normal play
speed and so on. Generally, the trick play streams include
a nine times fast forward stream and a nine times fast
reverse stream. Alternatively, 32 times normal fast forward
and fast reverse streams are also available. The term
30 source is used to describe the uncompressed video material
(601-format video) from which fast forward and fast reverse
bitstreams are generated.

Using the encoder 200, a fast forward MPEG video
bitstream is generated from an uncompressed video source
35 such that when the stream is played back linearly through a
standard MPEG compliant video decoder, the resulting imagery
contains every Rth frame of the original video sequence. As
such, the display of the sequence has a fast forward effect.

A fast reverse stream is simultaneously produced by the storage encoder 252 such that when linearly played back through a an MPEG compliant video decoder, the decoded stream produces a sequence of frames that play in reverse

5 relative to the original frame sequence.

The play bitstream is formed using a conventional MPEG-compliant encoder 202 that compresses a plurality of frames (N frames that form a group-of-pictures (GOP)). To form the trick play streams having N frame GOPs, the

10 subsampler 204 extracts one out of every R consecutive frames (arranged in increasing time code order) from the source sequence. The selected N frames are buffered in the frame buffer 206. For example, if R is two and the buffer stores N frames, the buffer stores frames 1, 3, 5, 7, 9, and

15 so on up to frame 2N+1. The buffer 206 stores N successive frames that define a GOP for the trick play bitstreams.

To produce a fast forward stream, the N frames from the buffer 206 are recalled under the control of the controller 210 and coupled sequentially into the real-time encoder 208.

20 The output is a compressed bitstream representing a fast forward GOP.

To produce a fast reverse stream, the N frames from the buffer 206 are recalled under the control of the controller 210 and are coupled in reverse time order into the encoder

25 208. Although two encoders could be used to produce each of the trick play streams independently, as long as R equals two or more, a single encoder can be used to produce both trick play tracks using time multiplexing technique. To perform the multiplexed encoding, the fast forward GOP is

30 encoded first, then the fast reverse GOP. After the buffer is filled with another N frames, the GOP pair is again encoded and so on. The recall order of the frames from the buffer and the multiplexing process are controlled by controller 110 by addressing the buffer in forward order for

35 the fast forward GOP and in reverse order for the fast reverse GOP.

The forward and reverse GOPs contain sequence start and sequence end codes such that, when stored in a mass storage

device along with the standard play stream, the bitstreams
are clearly delimited.

The forward and reverse GOP bitstreams are stored with
the play stream in a storage medium such as a disk drive

5   array or magneto-optical disk. The fast forward stream is
written sequentially, one GOP bitstream at a time, from the
lowest address to the highest address. The reverse
bitstream is stored in reverse order from highest address to
lowest address. The last byte in the reverse GOP is placed

10 in the highest address space of the reverse target file. As
such, the reverse GOP precedes, in address space, the first
frame of the immediately previously written reverse GOP.

The entire source material frame sequence is encoded in
this manner to simultaneously produce a play, a fast

15 forward, and fast reverse streams in real-time.

FIG. 3 illustrates the process by which a fast forward
stream is produced. Sequence 300 represents the RN frames
that have been subsampled from a video frame sequence at a
one of R rate from a video frame sequence and stored in the

20 buffer (e.g., R=2, then 2N frames are subsampled to form a
trick play GOP). The integer N is the number of frames that
are encoded into each GOP of the standard play stream.
These buffered frames are recalled from memory, encoded and
then associated with a normal play stream having a GOP of N

25 frames. The encoder (at step 302) repetitively produces a
sequence of GOPs 304 that are stored in increasing addresses
in memory as illustrated in sequence 306. The first GOP
(GOP 0) contains frames 1 to RN+1, the second GOP (GOP 1)
contains frames R(N+1)+1 through 2RN+1, the third GOP (GOP

30 2) contains frames 2R(N+1)+1 through 3RN+1, and so on. To
generalize, a GOP contains frames GR(N+1)+1 through
(G+1)RN+1, where G is the GOP number (e.g., 0, 1, 2, 3, ...),
R is the subsampling rate, and N is the number of frames in
a standard play GOP.

35 FIG. 4 illustrates the process by which a fast reverse
stream is produced. Sequence 400 represents the RN frames
that have been buffered after subsampling at one of R rate
(e.g., R=2 in FIG. 4). At step 402, these frames are

selected from the buffer in reverse order as illustrated at
404. The reverse order frames are encoded, at step 406, to
produce a sequence of GOPs 408 that are stored in reverse
time order in memory as illustrated in sequence 410.

5   Returning to FIG. 2, the real-time broadcast encoder
250 is, for example, a high data rate encoder (e.g.,
producing an 8 Mbps data rate MPEG bitstream) from a
real-time television broadcast. The source video is, for
example, a television feed of a sporting event. The source

10 video either arrives at the encoder in a frame-based digital
video format, such as 601 video, or is converted from some
other format into a frame-based video format prior to the
encoder. The real-time broadcast encoder operates
simultaneously with the storage encoder such that the real-

15 time broadcast bitstream is coupled to the transmission
system as the storage bitstreams are being stored in the
information server's data storage.

       Returning to FIG. 1 and simultaneously referring to the
flow diagram 500 of FIG. 5, The source video is encoded as a

20 broadcast stream in step 502 and as a storage stream in step
504. As described above, the storage bitstream is stored in
the information server memory at step 506, while the
broadcast bitstream is transmitted to the subscribers at
step 508. To facilitate broadcast of the broadcast

25 bitstream, the broadcast bitstream is coupled into path 116
to the video session manager 122. The video session manager
122 multiplexes the broadcast bitstream into a transport
stream along with all the other multimedia signals, control
signals and the like that are transmitted through the cable

30 transport subsystem 104 to the subscriber equipment 106. At
step 510, the subscriber terminal 136 demodulates,
demultiplexes and decodes the broadcast bitstream for
real-time display.

       To facilitate VCR-like functions with respect to the

35 broadcast bitstream, the subscriber terminal 136 can request
the stored bitstreams corresponding to the broadcast
bitstream by manipulating the input device 138 (step 512) in
the same manner as the device is used to control the display

of any other video asset. The subscriber, at any time, may
elect to review a portion of the program that has already
been watched. As such, the subscriber manipulates the input
device 138 (step 512) such that, at step 514, a "rewind" or
5 fast reverse command is sent from the subscriber terminal
136 to a modem 127 requesting rewind. The session control
manager 125 then instructs, at step 516, the information
server 108 to recall the fast reverse stream associated with
the broadcast bitstream and send, at step 518, the fast
10 reverse stream to the requesting subscriber, i.e., the
transmission to the subscriber is now changed from a
broadcast transmission to a pointcast transmission. At step
520, the subscriber terminal demodulates, demultiplexes and
decodes the transport stream carrying the reverse play
15 stream such that the display 140 depicts the broadcast video
running quickly backwards at some rewind rate, e.g., nine
times standard play.

     At some point during the "rewinding" of the video
sequence, the subscriber may, at step 522, elect to "play"
20 the video sequence. By selecting the "play" button on the
input device, the subscriber terminal sends, at step 524, a
request to the session control manager 125. The session
control manager 125 then requests, at step 526, the standard
play stream to be sent, at step 528, to the subscriber
25 starting at the location at which the video sequence had
been "rewound", i.e., whatever frame number the subscriber
was viewing at the time the play button was depressed with
be the starting frame number that is sent to the subscriber
in the play stream. At step 530, the play stream is then
30 demodulated, demultiplexed, and decoded such that the
display in the subscriber's home transitions from rewind to
play. The subscriber may then watch the program from this
point forward or may request another trick play function.

     For example, at step 532, the subscriber selects a fast
35 forward function to move through the video quickly, e.g.,
nine times standard play speed. If the subscriber elects to
fast forward through the video, the subscriber terminal once
again sends, at step 534, a request to the session control

manager 125 which, in turn, requests, at step 536, the
information server to recall the fast forward stream
starting at the frame (or near the frame) that the user was
then watching in the play stream. The session control
5   manager 125 sends, at step 538, the fast forward stream to
the subscriber. At step 540, the fast forward stream is
then demodulated, demultiplexed and decoded to present a
fast forward display. This stream will be transmitted until
there is no longer any fast forward data, i.e., the storage
10   bitstream catches up with the broadcast stream and an end of
file (EOF) indicator is reached. At that occurrence, the
subscriber terminal, at step 542, automatically switches
the subscriber back to the broadcast stream. At step 544,
the subscriber terminal 136, demodulates, demultiplexes and
15   decodes the broadcast stream.

      An alternative to requiring the subscriber to fast
forward to catch up to the broadcast stream is to provide a
"catch up" button that, when depressed, causes the
subscriber terminal to instantly transition from decoding
20   the storage bitstream to decoding the broadcast bitstream.
.This button may be a hardware button on the input device or
a software button that is displayed on the television
display.

      Although various embodiments which incorporate the
25   teachings of the present invention have been shown and
described in detail herein, those skilled in the art can
readily devise many other varied embodiments that still
incorporate these teachings.